Can climate models simulate the atmospheric heat budget and does it matter?

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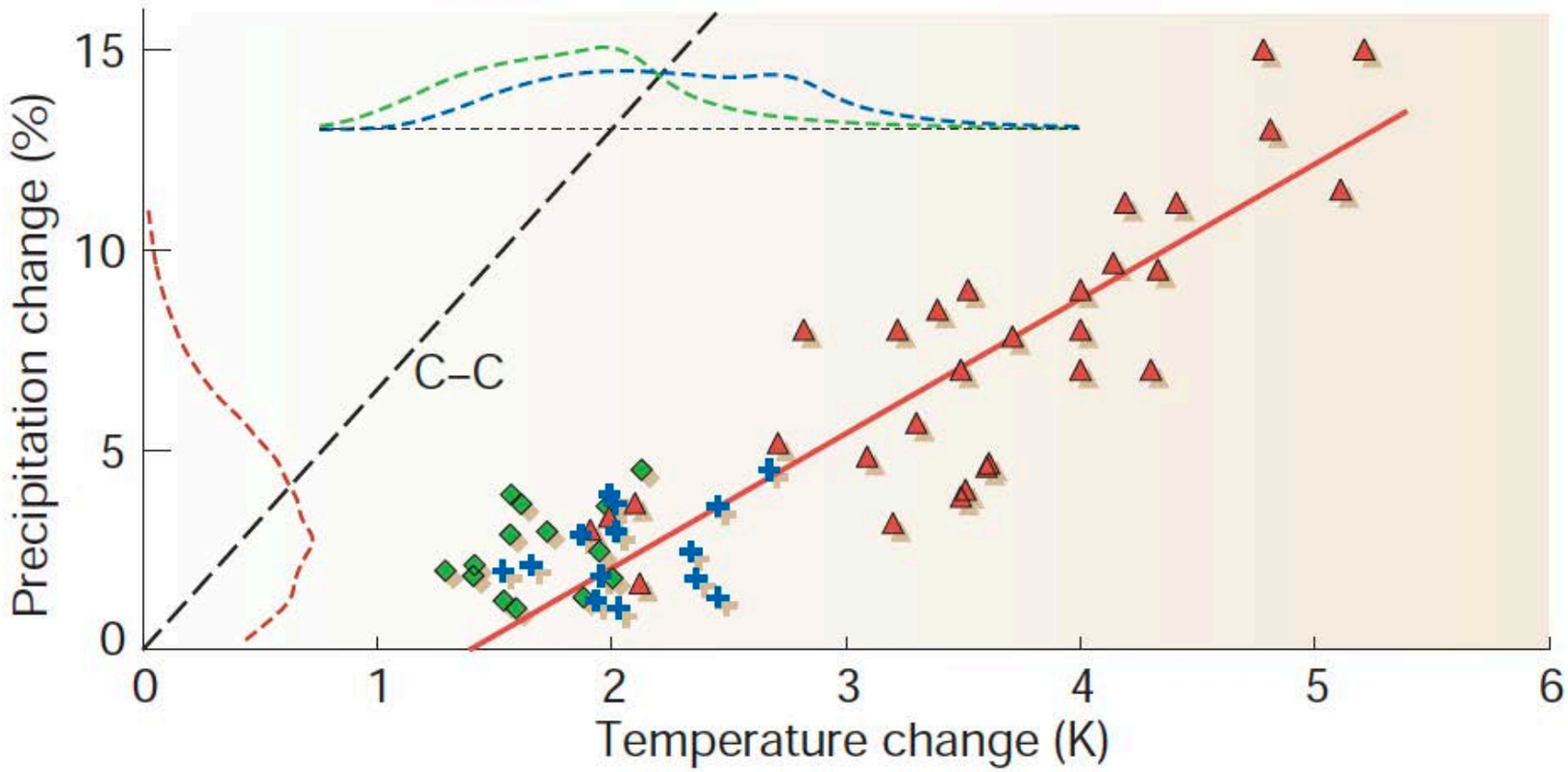
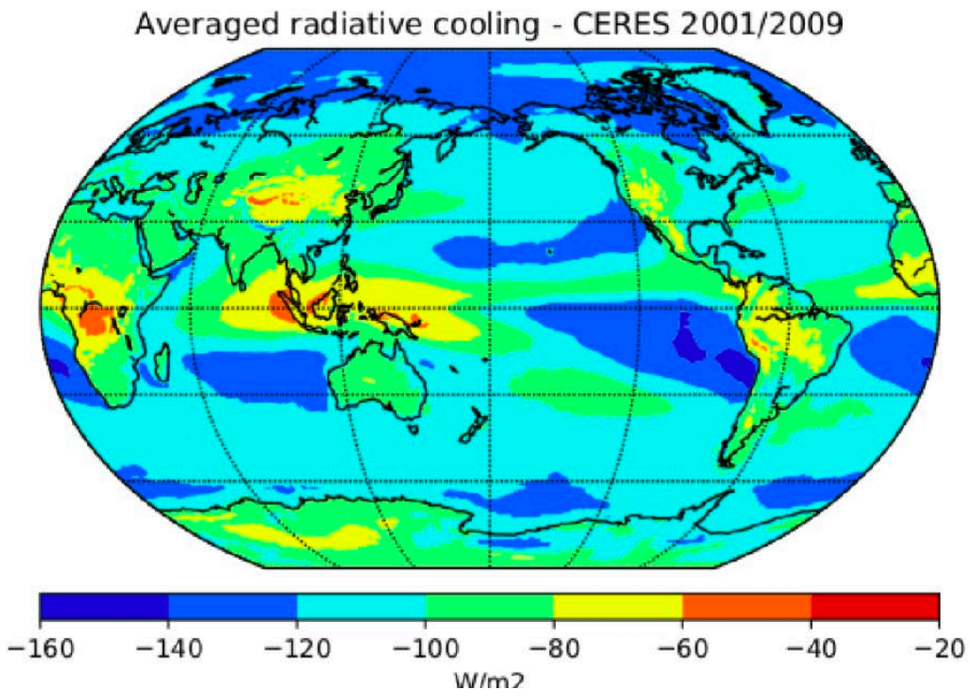
With Leonore Jungandreas, Martin Singh, and Penelope Maher

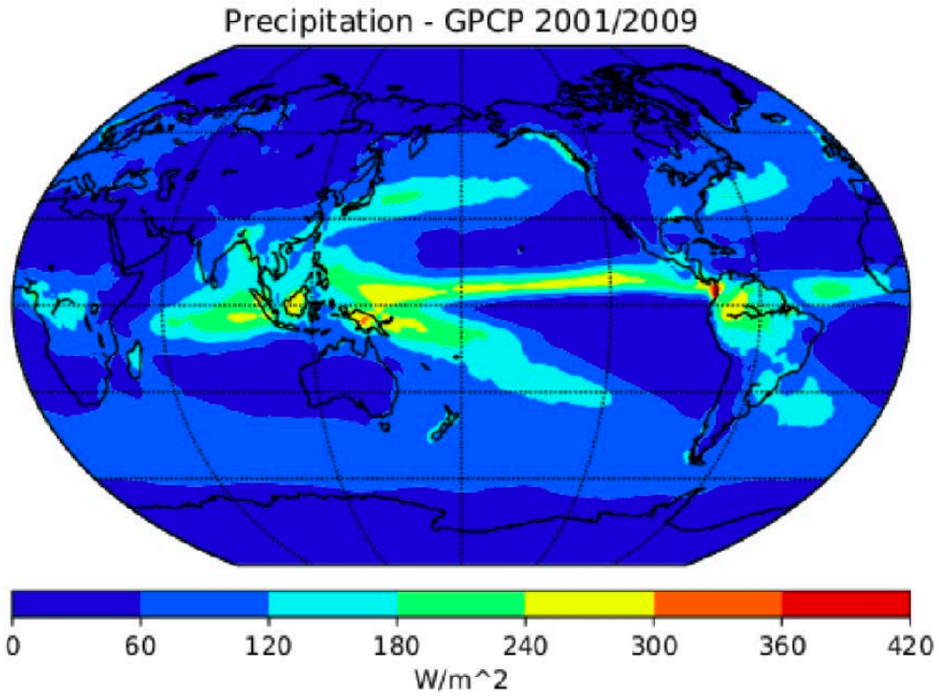
We know that the energy budget of the atmosphere constrains rainfall and its changes in the hydrological cycle in a warming climate

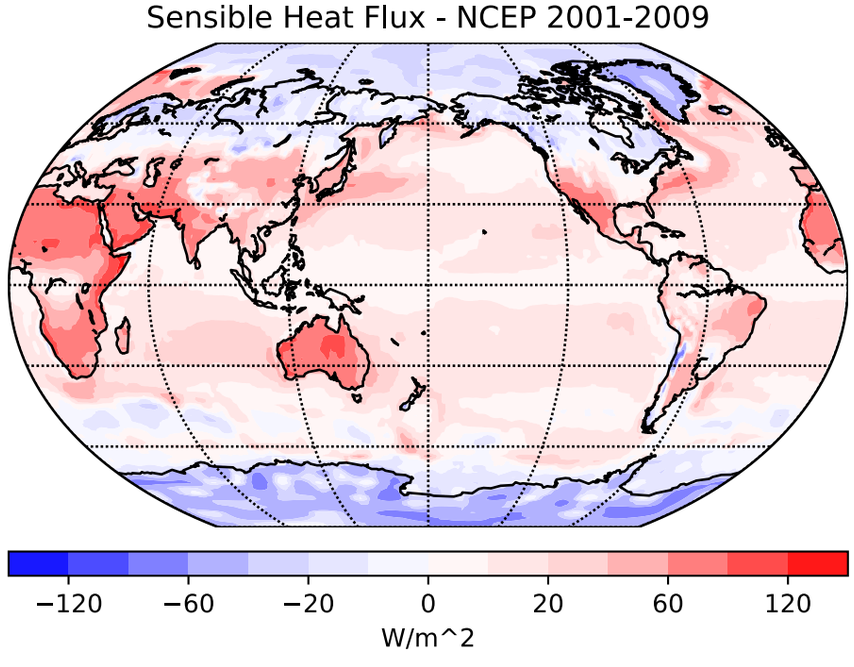


Allen and Ingram, 2002

For a number of reasons, we tend to focus on TOA and SFC budgets, and rarely look at the atmospheric heat budget.







$$< Q_{Rad} > = -104.5 W/m^2$$

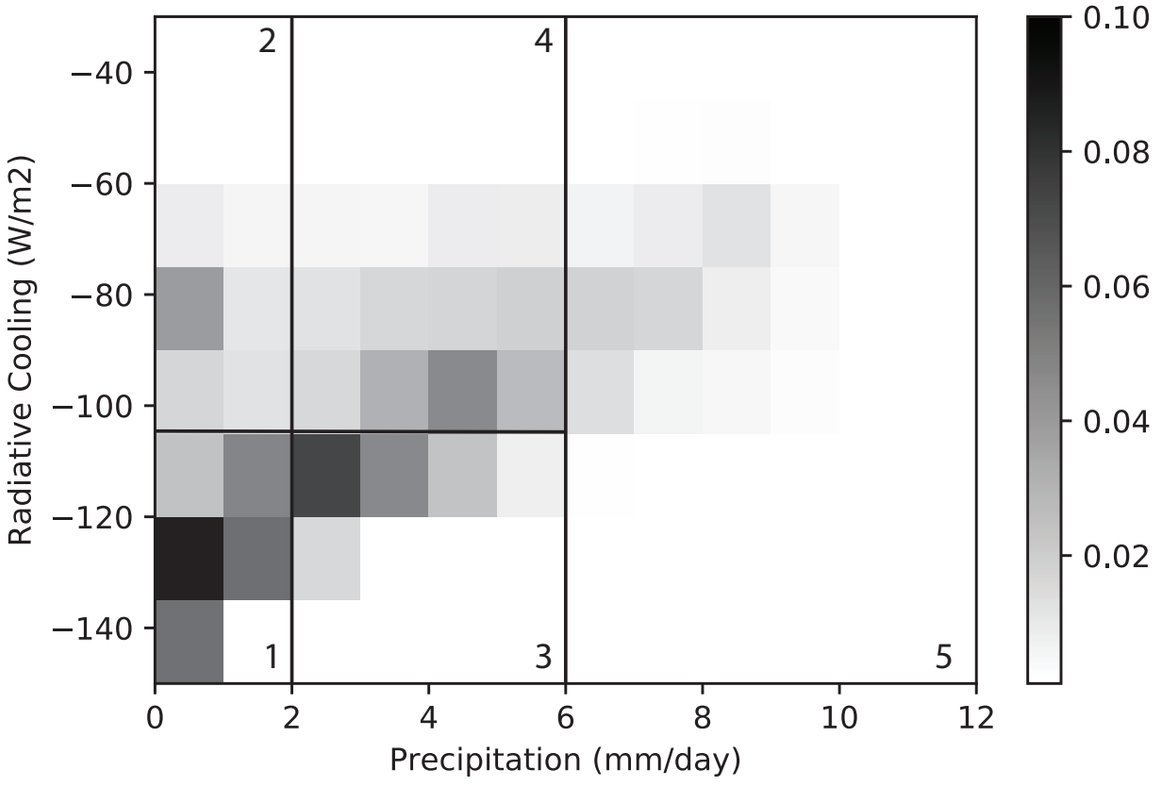
$$< P > = 85.2 W/m^2$$

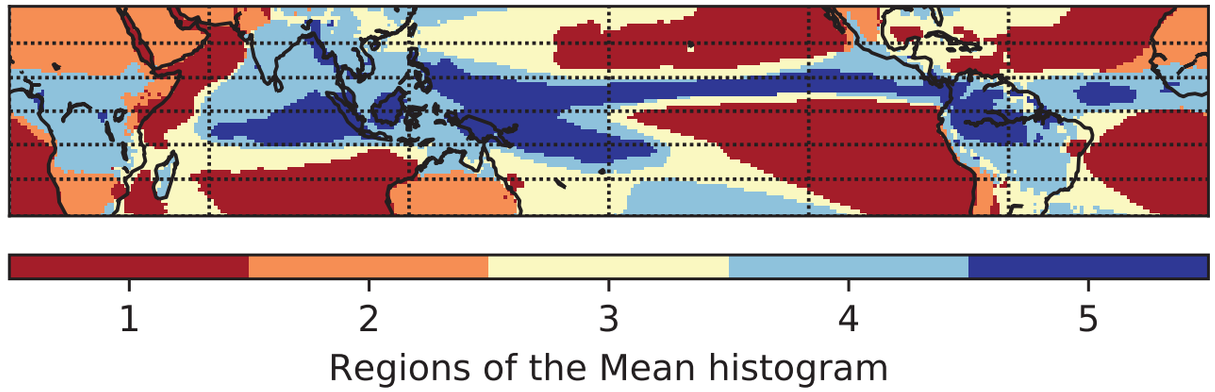
$$< SSHF > = 22.6 W/m^2$$

$$Residual = 3.3 W/m^2$$

Jakob et al., 2019

We know that the energetic constraints in the atmosphere are highly non-local and involve the circulation as an intrinsic part of establishing equilibria.

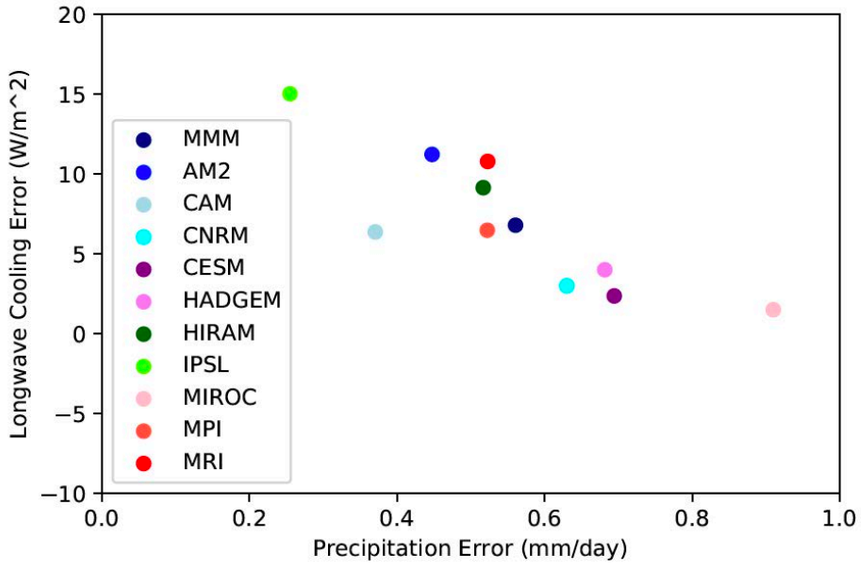


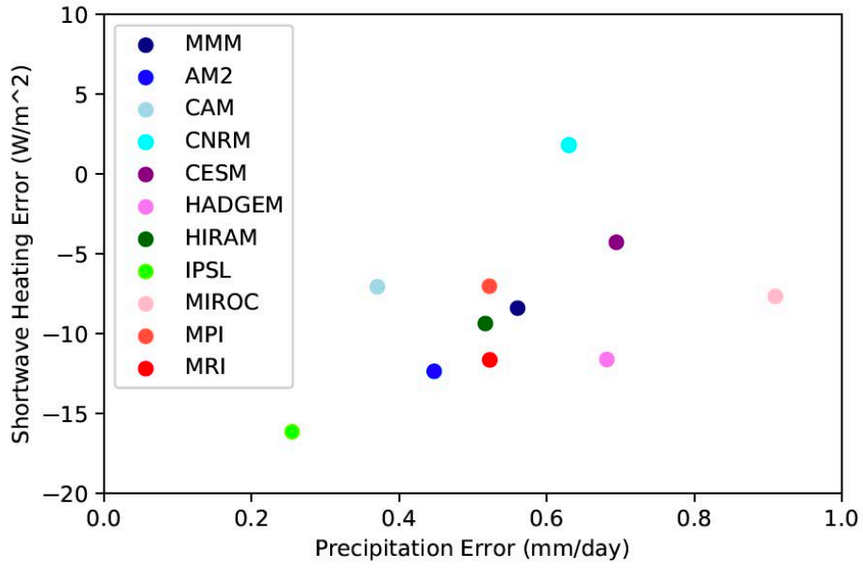


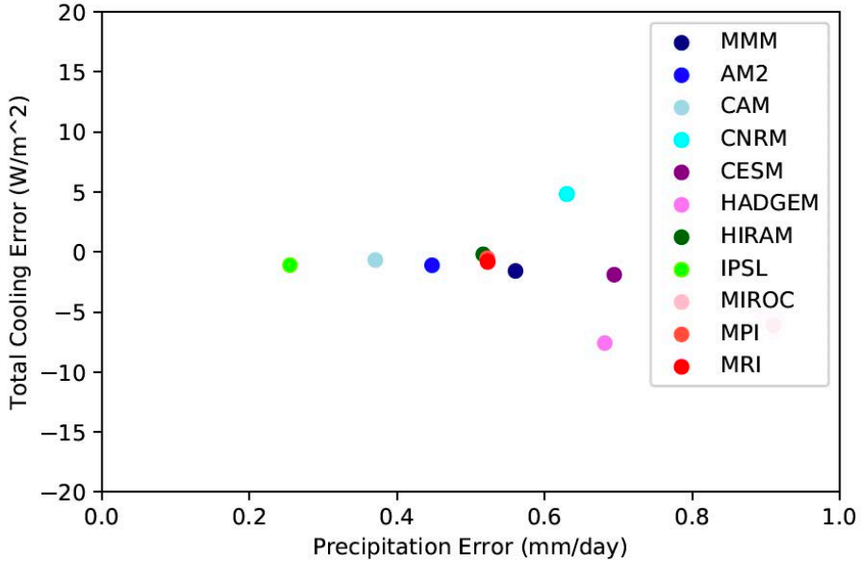
1 = Strong cooling, no rain
2 = Weak cooling, no rain
3 = Strong cooling, medium rain
4 = Weak cooling, medium rain
5 = Strong rain, never cools strongly

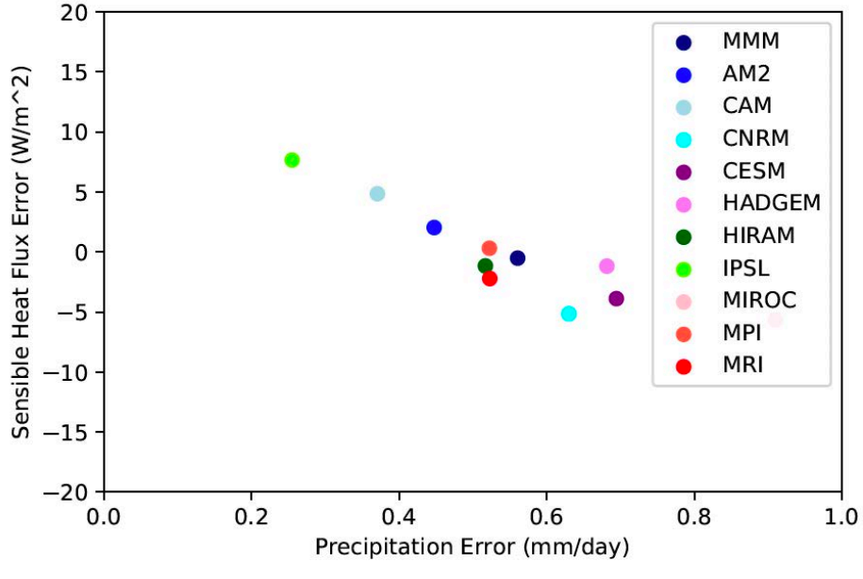
Jakob et al., 2019

Don’t underestimate the role of the sensible heat flux.

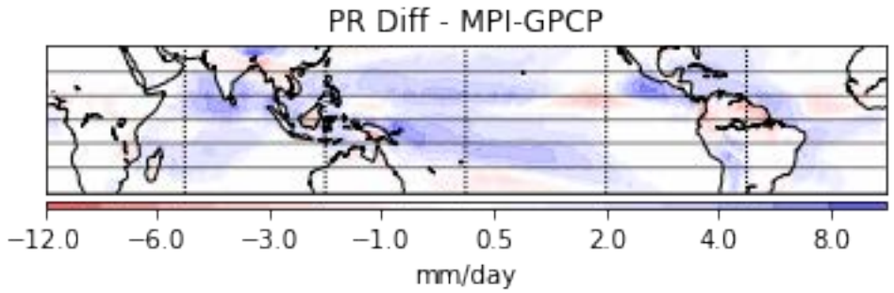


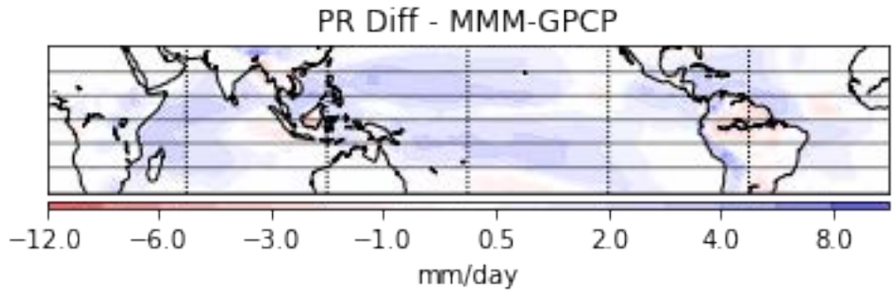


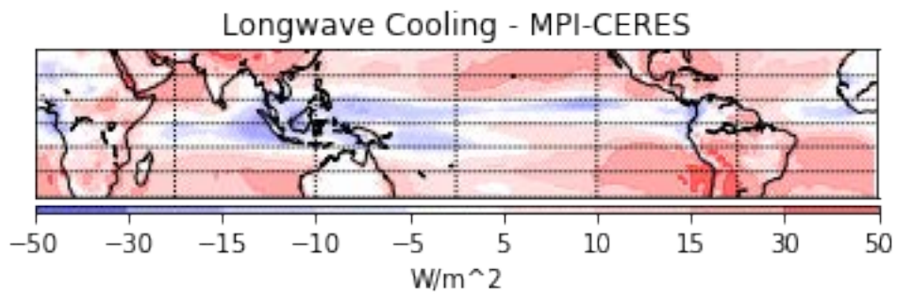


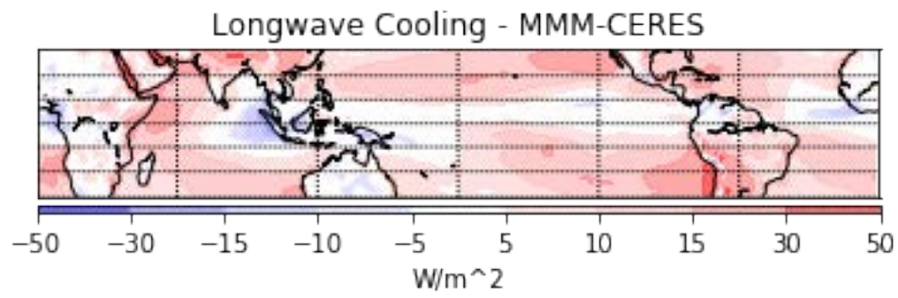


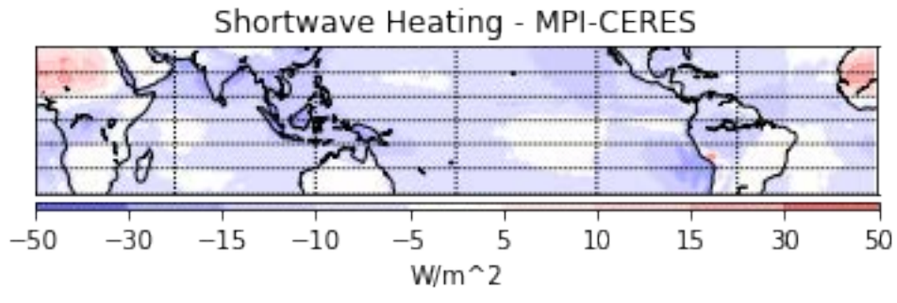
Model errors in longwave cooling are compensated by errors in shortwave heating.

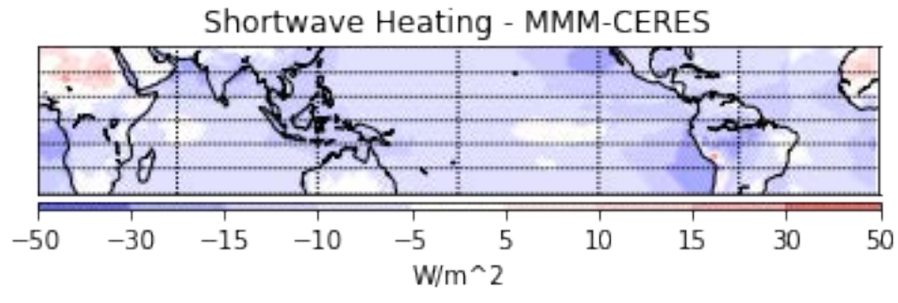


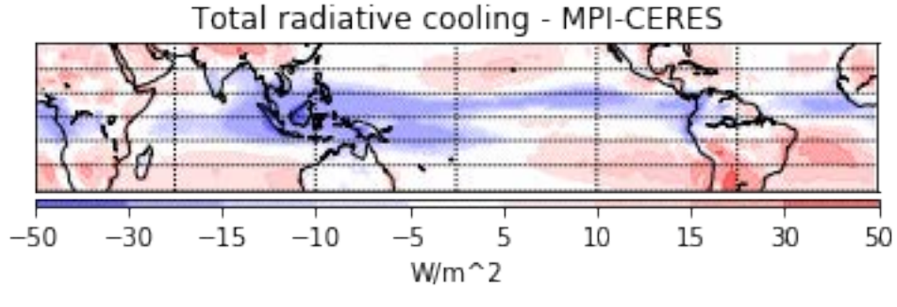


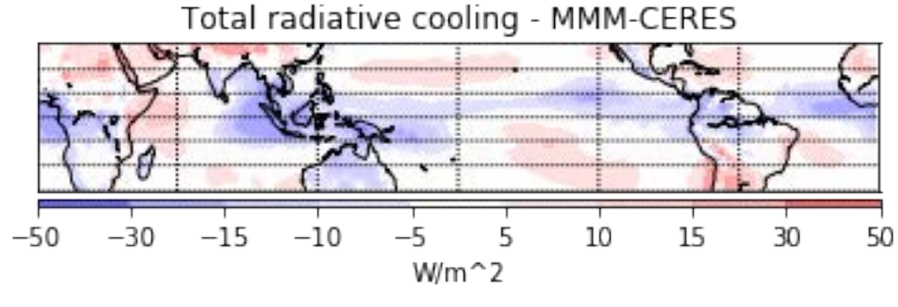




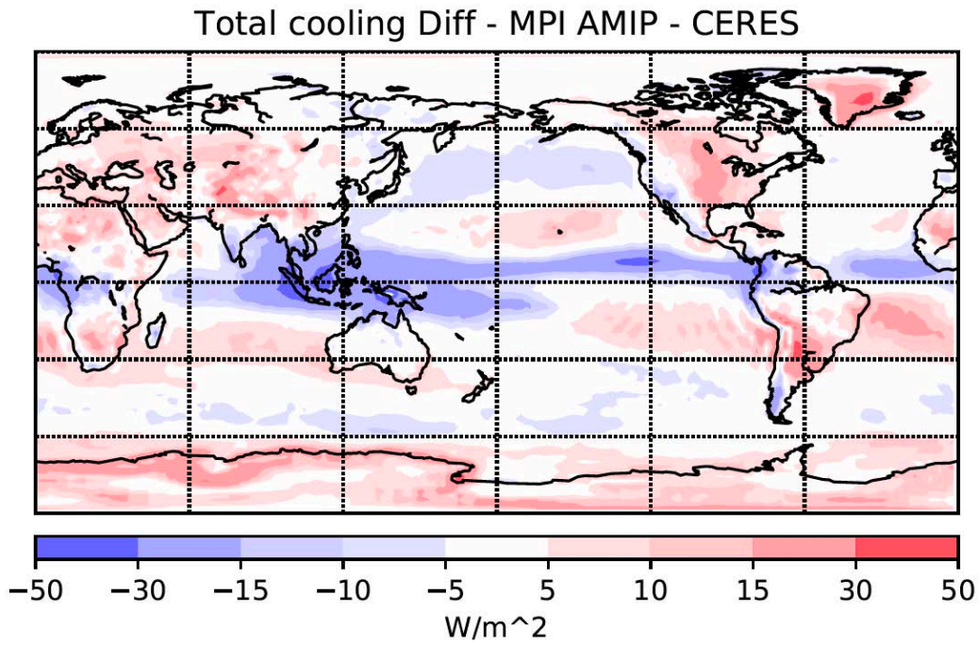


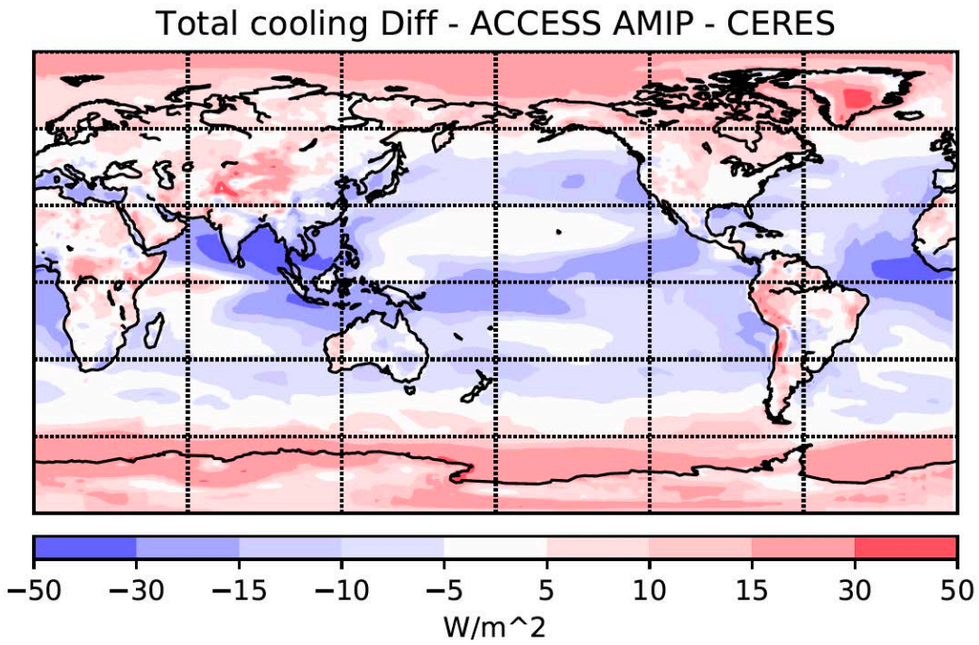


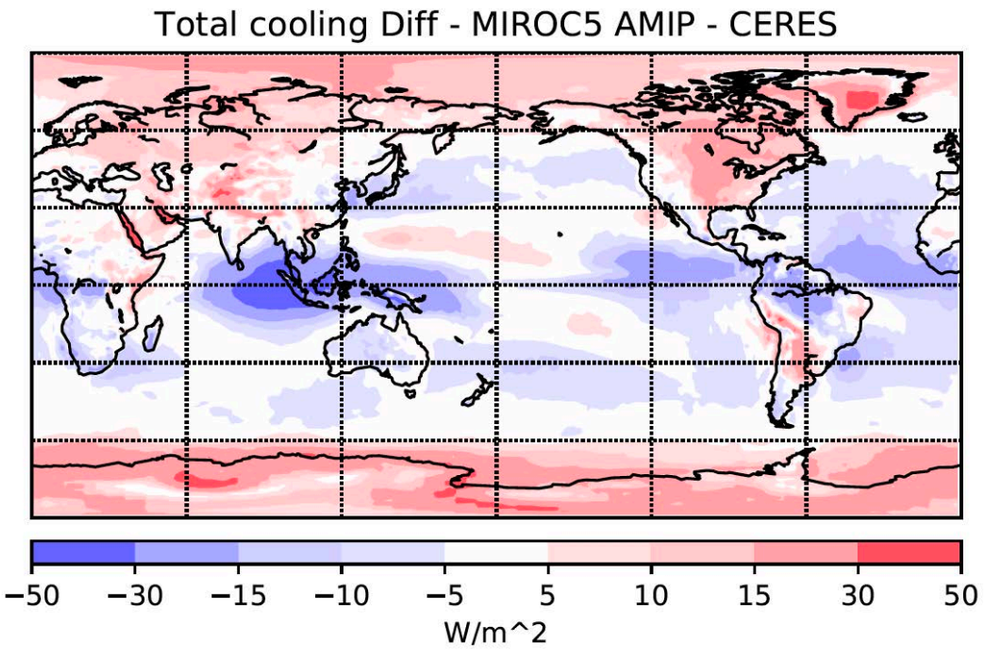


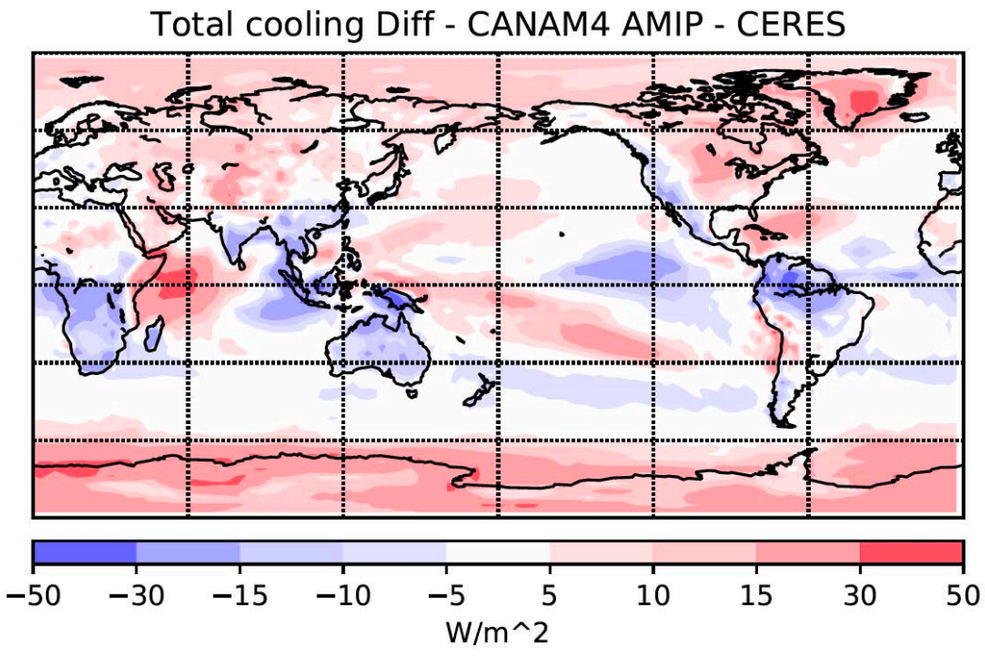


Going global and using a second radiation data set (ISCCP FH) mostly confirms the tropical story, but reveals uncertainty!









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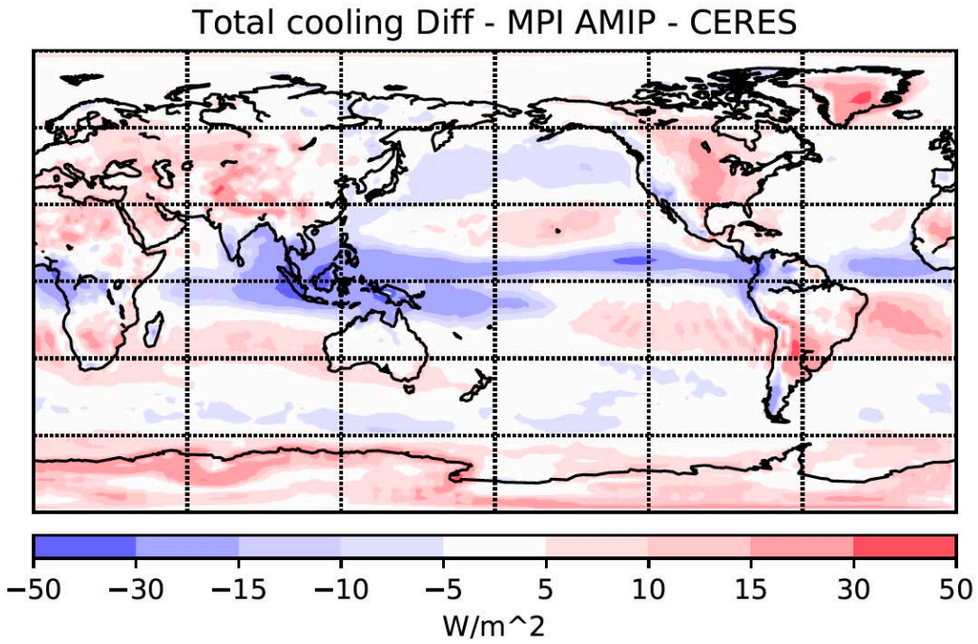

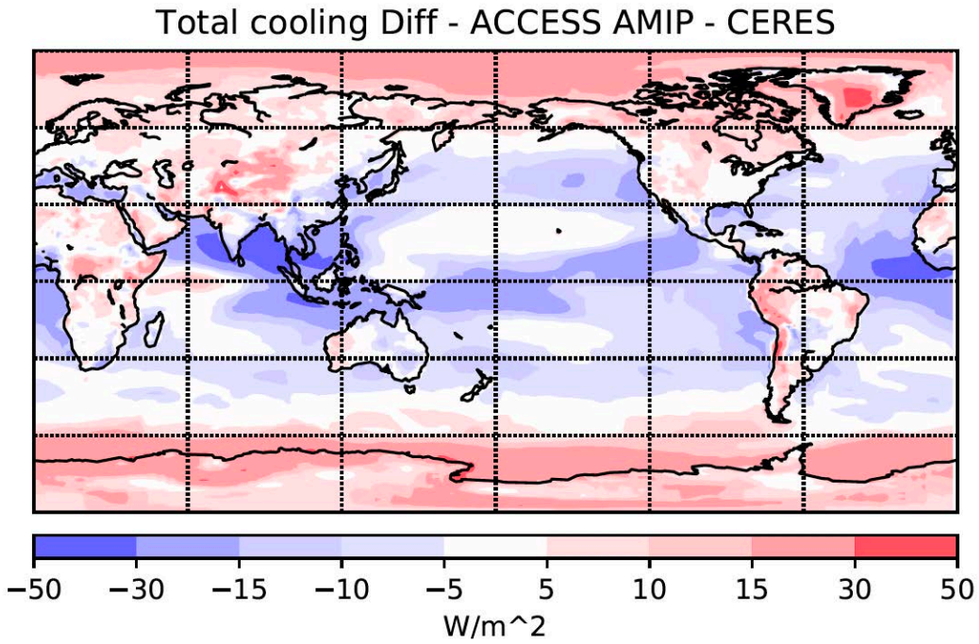

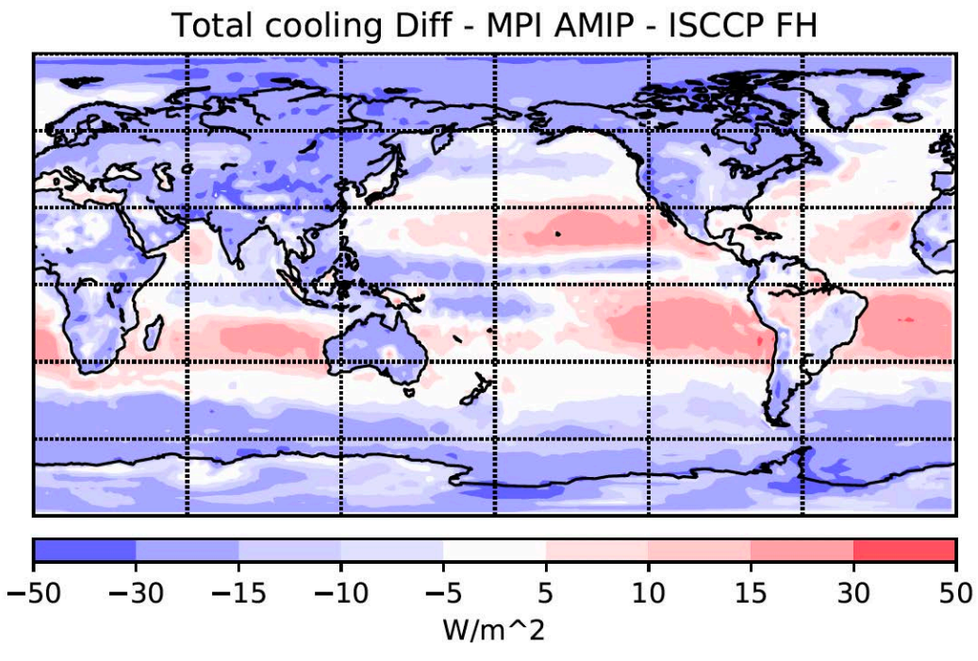

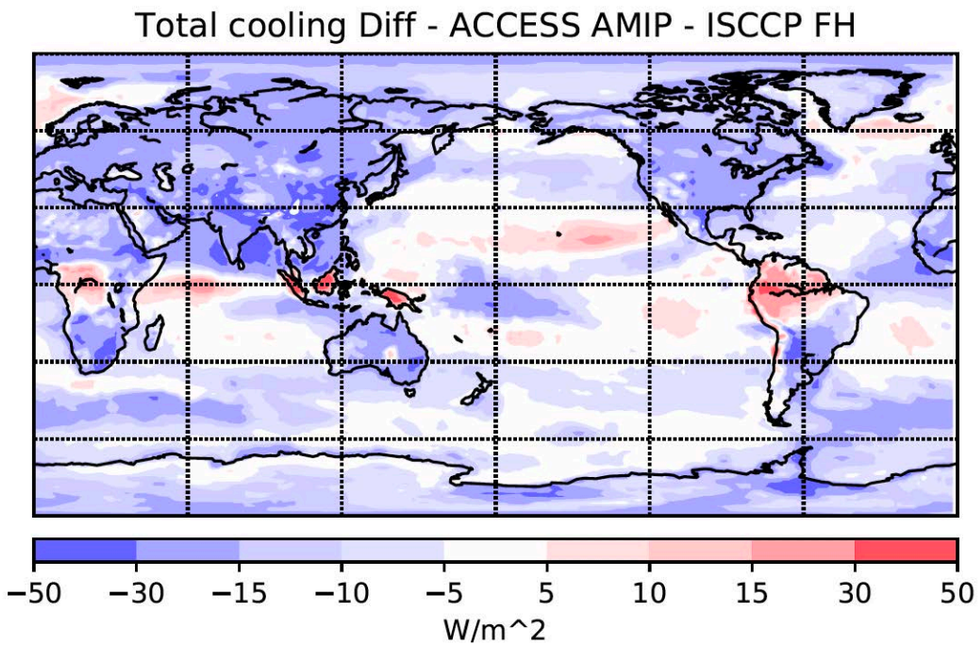

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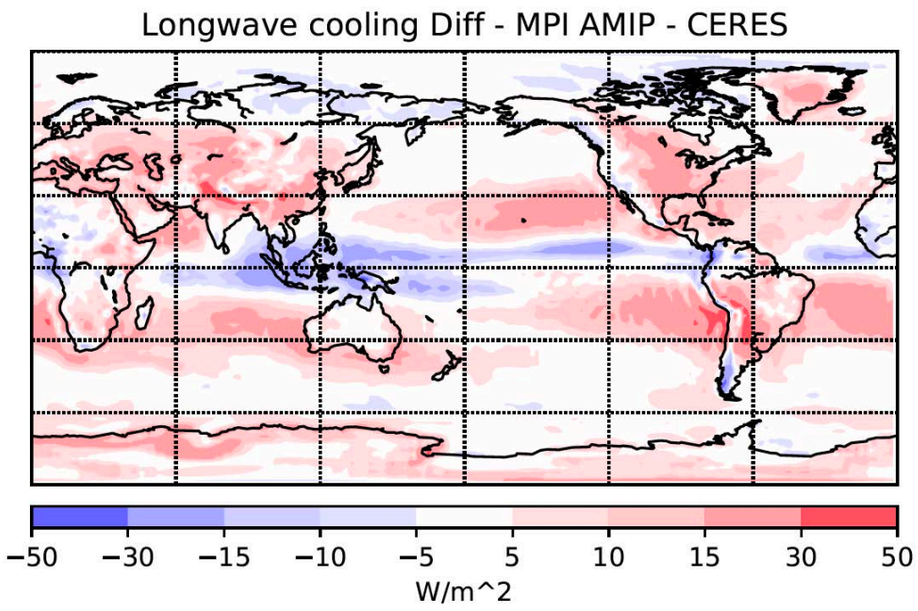

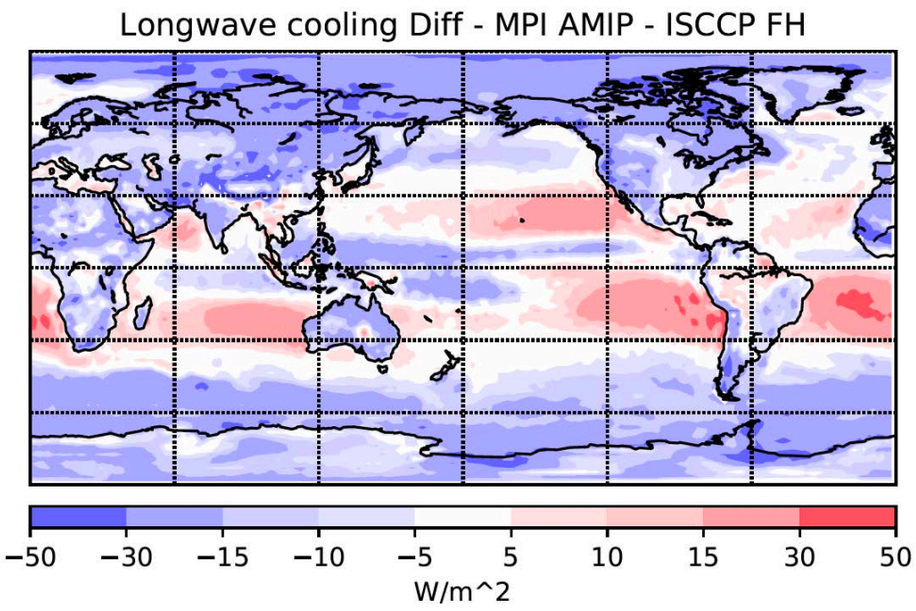

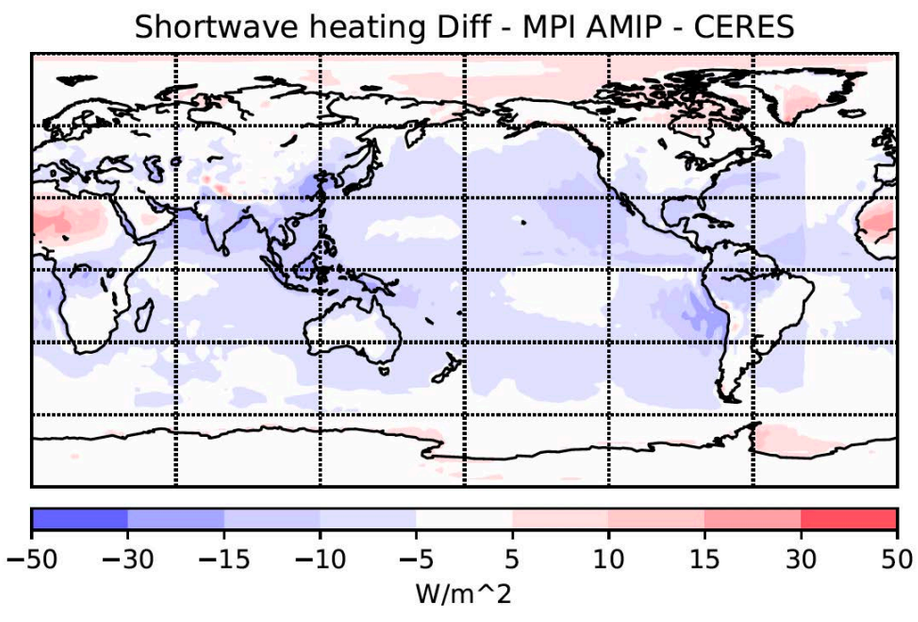

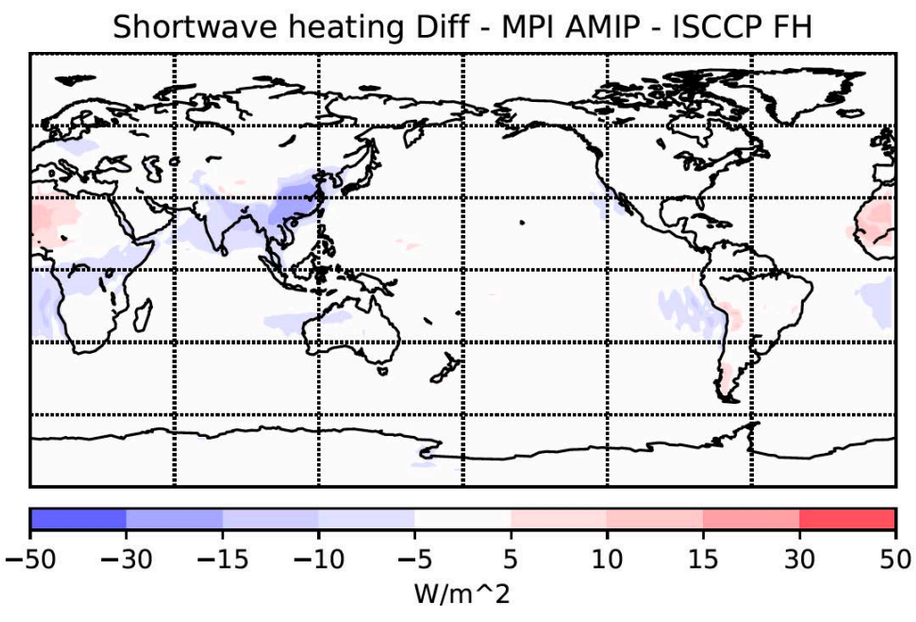

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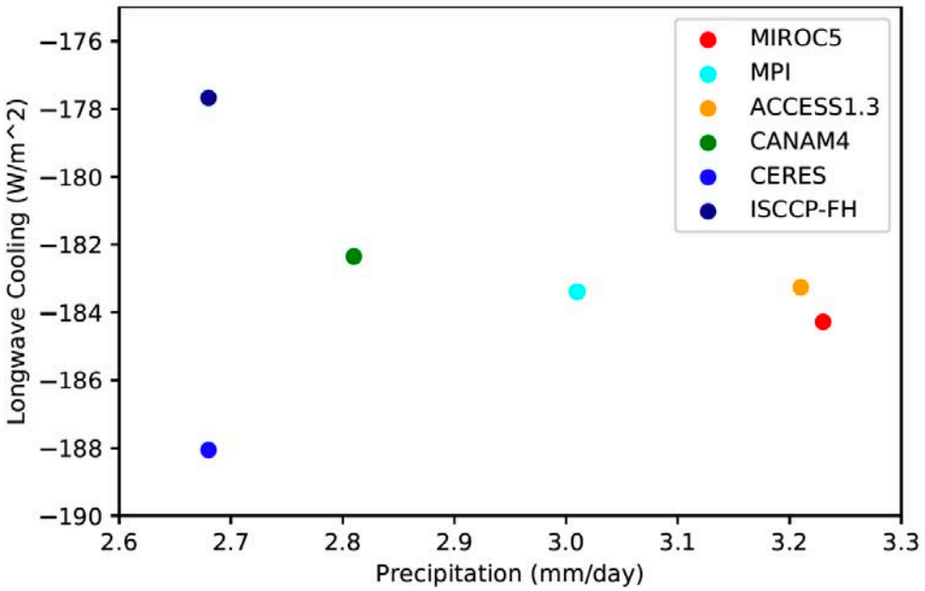
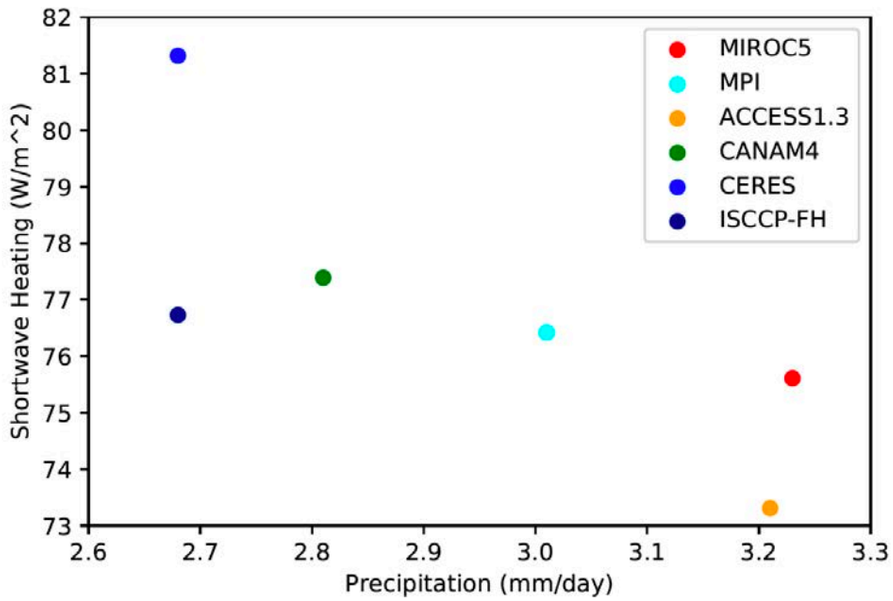
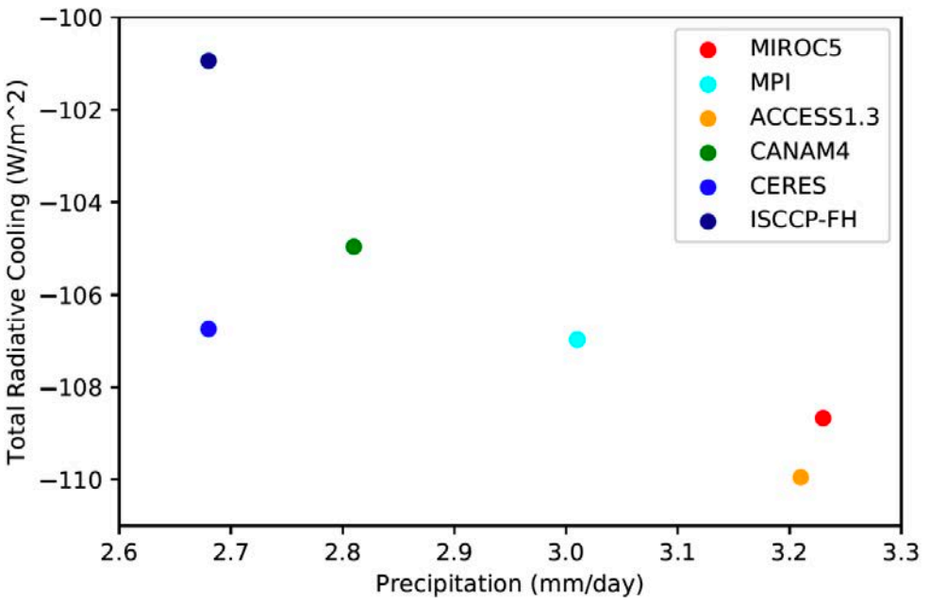
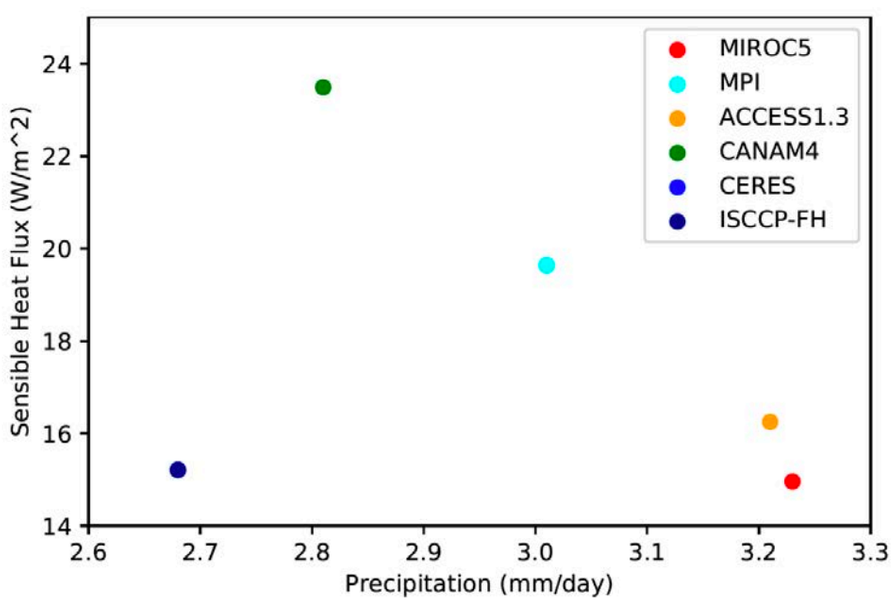
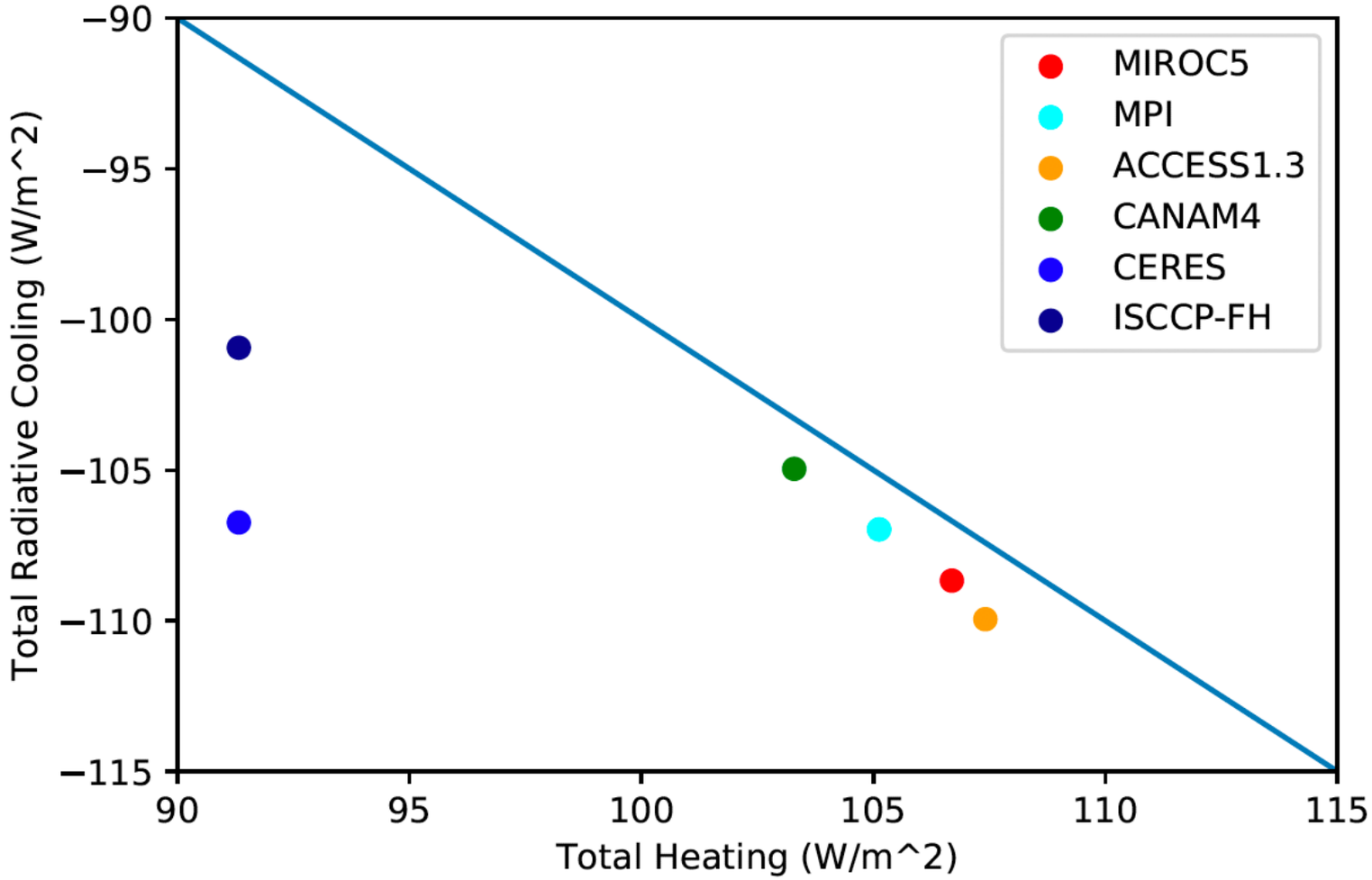






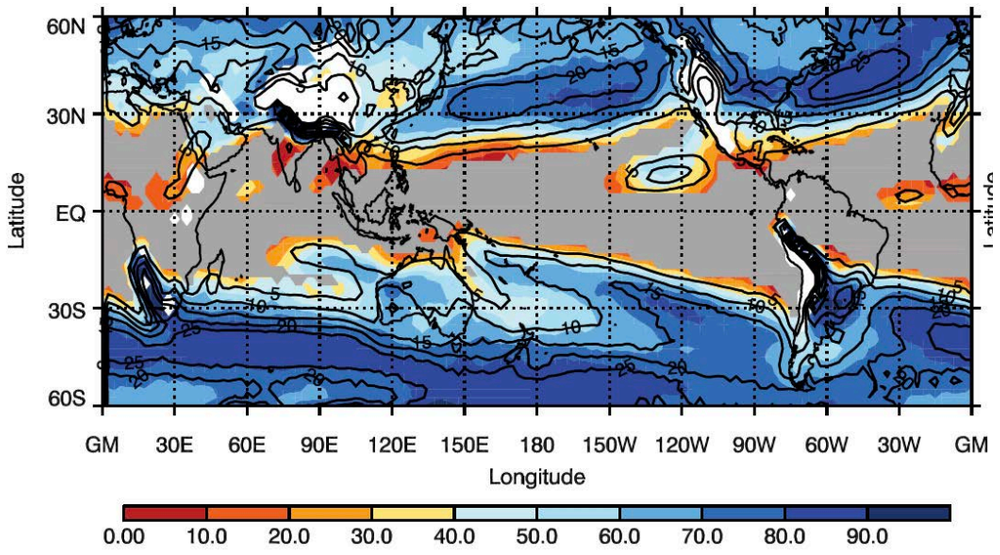


Models are closer to (but not in) balance than the observations. They lie on the higher estimate of radiative cooling and have a more heating than the observations.

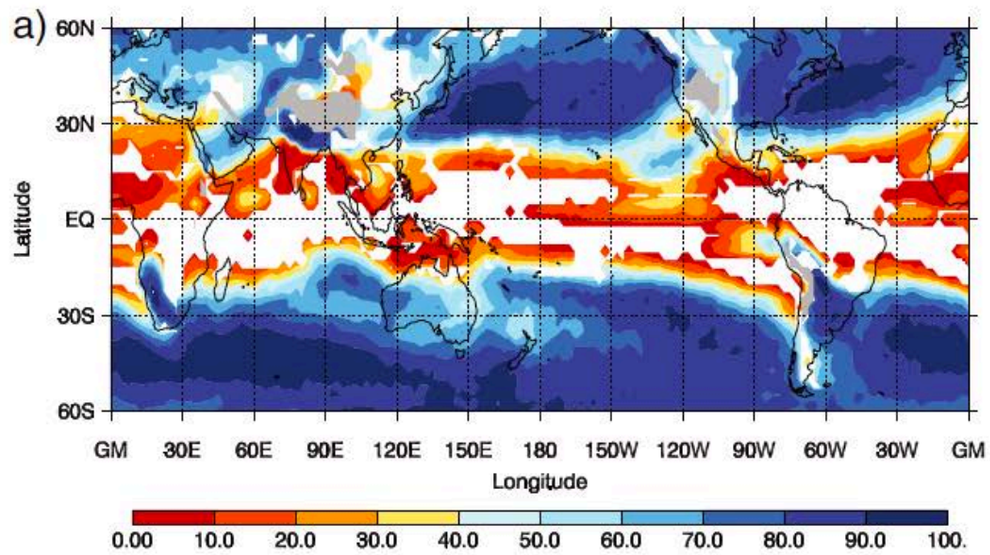


All this does and does not matter, as rainfall is not delivered through equilibria. It is made by weather features! Those in turn are steered by the large-scale features (e.g. jets). We need to understand this complex multi-scale chain!

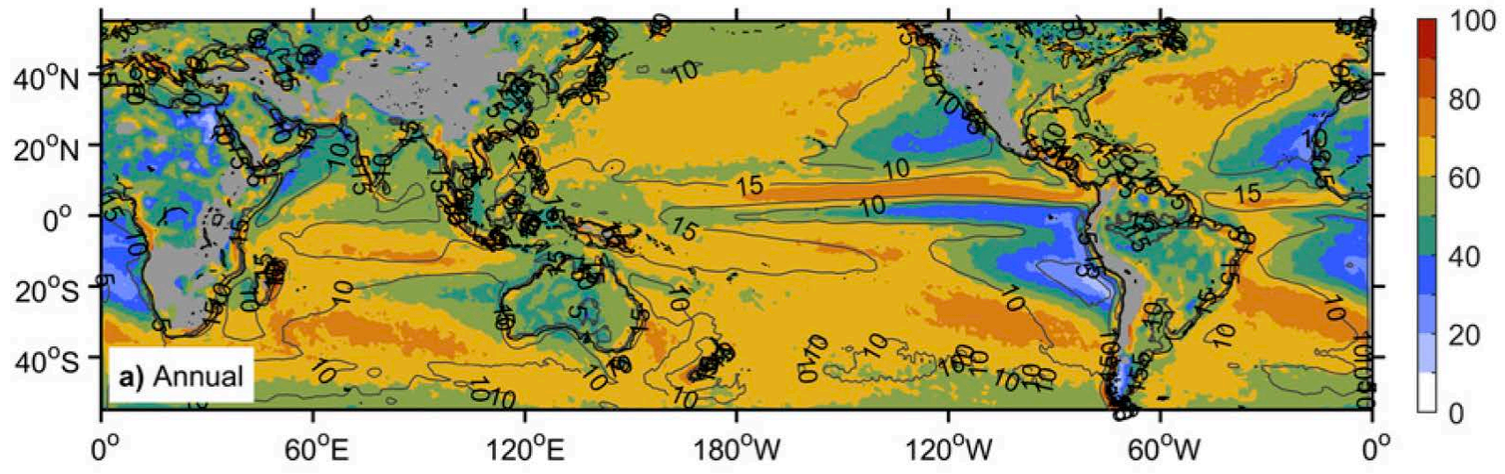
Proportion of rainfall associated with fronts



Proportion of extreme rainfall events associated with fronts



Proportion of rainfall associated with convergence lines



Catto et al., 2012, Catto and Pfahl, 2013; Weller et al., 2015